



CAPACITY OF THE NATIONAL  
AIRSPACE SYSTEM

4

## 4 CAPACITY OF THE NATIONAL AIRSPACE SYSTEM

The two basic elements of the NAS, its airports and its airspace, are equally important in determining the capacity of the system. At any given time, that capacity is determined by conditions at the airports and their management by local operators, and by the status of the airspace and its management by the FAA. Only through the coordinated management of both elements can the air transportation system function effectively.

When either NAS element is adversely affected, system capacity is reduced. When conditions prevail that reduce the capacity of a large airport (bad weather, winds that necessitate the use of a less than optimal runway configuration, runway closure, and so forth), the effects ripple through the surrounding terminal airspace and, if those conditions persist, through en route airspace as well. These problems in the airspace can ultimately impact operations at other airports. Similarly, if bad weather in an en route sector reduces airspace capacity and restrictions are placed on traffic entering or transiting that airspace, the effects will soon reach nearby airports.

### 4.1 Airspace Capacity

Airspace capacity is the theoretical maximum number of aircraft that physically can be in a volume of airspace at a specific point in time. Actual airspace capacity is very difficult to measure because it is the result of the interaction of a number of interdependent factors that are constantly changing. Thus, capacity will be different from one moment to the next.

In operation, airspace capacity is the ability of the air traffic control system to safely manage the flow of aircraft from departure to destination at the times sought by the aircraft operators. The safe use of that airspace capacity is made possible by a complex network of communications, navigation, surveillance, and automation systems. This network is run by the FAA's air traffic services organization, including controllers, traffic management specialists, and a staff of support technicians. The efficiency of the use of airspace is contingent upon the procedures implemented by air traffic control for the safe conduct of operations through the airspace. These procedures vary by operational domain: oceanic, en route, and terminal airspace are structured differently.

In the oceanic domain, the lack of direct radar surveillance imposes a constraint on the capacity of the airspace. Safe separation requirements are significantly greater here because air traffic controllers rely on infrequent radio communications to monitor aircraft position. Separation in oceanic airspace is 100 nautical miles horizontally and 2,000 feet vertically. In the en route domain, where there is direct radar surveillance, separation varies by altitude. Traffic below FL290 must be separated from other aircraft by five miles and 1,000 feet. Traffic at FL290 or above must be separated by five miles and 2,000 feet. Aircraft flying in en route airspace follow jet routes or other flight paths that have been specified in a flight plan that has been filed with the FAA.

Traffic in terminal airspace, where aircraft fly more slowly, must be separated from other aircraft by three miles and 1,000 feet.<sup>5</sup> Aircraft flying in terminal airspace follow standard instrument departures (SIDs) and standard terminal arrival routes (STARs), or the directions of an air traffic controller.

5 On approaches and departures, longitudinal separation standards are increased when different types of aircraft are following one another in order to limit the impact of wake vortices. For example, if the leading aircraft is a so-called heavy, such as a B-747, another heavy aircraft must maintain four miles longitudinal separation, a large aircraft must maintain five miles, and a small aircraft must maintain five or six miles.

### 4.1.1 Factors Affecting Airspace Capacity

Airspace capacity is theoretically infinite, in that the cubic volume of airspace is sufficient to allow all existing aircraft to be airborne simultaneously and not be in conflict with one another. In reality however, the nation's air traffic is not evenly distributed throughout the day or among all airports. Operations tend to be concentrated in the airspace near the major airports and along defined routes, particularly during the most convenient travel times. At these periods of peak operations, demand may exceed the airspace capacity in these locations. When this occurs, air traffic control flow management and traffic separation standards ensure that actual operations do not exceed the airspace capacity. The trade-off for such safety assurance measures is that some aircraft are delayed.

Similarly, hazardous weather phenomena such as thunderstorms or icing conditions can reduce airspace capacity or close the airspace entirely, necessitating changes in traffic flows and air traffic control separation requirements. Poor weather conditions dictate the re-routing of aircraft, thereby delaying some planes and increasing demand on other airspace. If the hazardous weather is prolonged, airspace capacity limitations may have a ripple effect, causing ground holds, delayed arrivals, and flight cancellations.

Airspace capacity is also limited by the use of special use airspace. Most special use airspace is reserved for various military training and operational needs, effectively withdrawing that volume of airspace from use by air traffic, and reducing system capacity.

## 4.2 Airport Capacity

An airport is divided into airfield and landside sections. The airfield is comprised of runways, taxiways, apron areas, aircraft parking positions, air traffic control facilities, and navigational aids. The landside consists of the terminal building and the associated access roads. Although landside capacity is an important aspect of the air transportation system, it is entirely managed by the airport operators and is therefore beyond the scope of this document. Consequently, the use of the term airport capacity in this chapter refers to airfield capacity.

The number and placement of runways and taxiways, the types of navigation aids, and the types of air traffic control equipment and facilities determine airport capacity. But other variables such as aircraft performance, the mix of aircraft types, pilot proficiency, weather, and runway closures affect how much of an airport's capacity can be used at a given time. The capacity in use is often less than the capacity that would be available if there were no such limitations.

An airport's capacity is highest under visual flight rules (VFR) weather conditions. All the runways can be used for landing, including those for which no instrument approach is available, as well as intersecting runways. In addition, pilots can assume responsibility for aircraft spacing, delay configuring the aircraft for landing until it is closer to the runway, and need not fly instrument approach procedures.

The capacity of an airport is actually a range of values. Each value is associated with a specific runway configuration, airport operating conditions (including ceiling and visibility), the mix of aircraft types using the airport and the proportions of arrivals and departures. Figure 4-1 shows the actual hourly departure and arrival rates at the large-hub airports during CY 1999.<sup>6</sup>

<sup>6</sup> Total operations are less than the sum of hourly arrivals and departure rates because some runway configurations allow more arrivals and others allow more departures, while total operations reflect the number of arrivals and departures that can be handled simultaneously.

**Figure 4-1**Hourly Arrival and Departure Rates  
at Large Hub Airports, CY 1999

Airport	ID	Departures	Arrivals	Total Operations
Hartsfield Atlanta International	ATL	99	98	190
Boston Logan International	BOS	58	55	106
Baltimore Washington International	BWI	35	36	61
Charlotte-Douglas International	CLT	58	53	102
Greater Cincinnati/Northern Kentucky Intl	CVG	75	62	124
Ronald Reagan National	DCA	39	39	71
Denver International	DEN	64	63	113
Dallas/Fort Worth International	DFW	104	111	212
Detroit Metropolitan Wayne County	DTW	72	69	131
Newark International	EWR	54	51	93
Fort Lauderdale International	FLL	31	30	54
Washington Dulles International	IAD	70	71	112
George Bush Intercontinental/Houston	IAH	59	62	112
New York John F. Kennedy International	JFK	50	56	82
Las Vegas McCarran International	LAS	42	42	76
Los Angeles International	LAX	81	83	145
New York LaGuardia	LGA	42	42	79
Orlando International	MCO	40	43	73
Miami International	MIA	60	60	106
Minneapolis-St. Paul International	MSP	66	68	118
Chicago O'Hare International	ORD	100	99	183
Philadelphia International	PHL	57	60	103
Phoenix Sky Harbor International	PHX	56	57	104
Greater Pittsburgh International	PIT	70	68	105
San Diego International Lindbergh Field	SAN	27	26	46
Seattle-Tacoma International	SEA	51	48	83
San Francisco International	SFO	50	50	90
Salt Lake City International	SLC	42	47	77
Lambert-St. Louis International	STL	61	62	111
Tampa International	TPA	33	33	57

Total operations in this figure are less than the sum hourly arrival and departure rates. The differences results from implementation of various runway usage configurations, some which allow more arrival, others which allow more departures, while total operations reflect the number of arrivals and departures that can be handled simultaneously.

For the large-hub airports, ETMS is 89.4% of official traffic counts. The major reason for this difference is that ETMS does not capture any general aviation VFR traffic. Therefore, these percentile values may slightly understate actual rates.

Arrival and departure rates from 0700 to 2159 local time.

Source: Enhanced Traffic Management System; excludes Honolulu (HNL).

### 4.2.1 Factors Affecting Airport Capacity

The primary determinant of an airfield's capacity is its physical design: the number, length, and location of runways, intersections, taxiways, gates, and the distance between parallel runways. Nonetheless, capacity varies greatly within the absolute limitations of an airport's physical design, and this variability of capacity is an important factor in airport operations and aircraft scheduling. A variety of considerations affect an airport's most efficient runway configuration. These considerations can be grouped into five categories: Airfield Resources, Visibility and Meteorological Conditions, Air Traffic Control Procedures, Noise Considerations, and Aircraft Demand.

#### **4.2.1.1 Airfield Resources**

The number, length, and orientation of an airport's runways and taxiways determine the operational practices that can be used under different weather or demand conditions. The lighting and navigational aids available at an airport, such as one or more Instrument Landing Systems (ILS), determine whether particular runways can be used when visibility is poor. A distance of more than 4,300 feet between parallel runways allows parallel independent ILS approaches to be flown, helping to increase capacity. In some cases, obstructions in the approaches, runway length or weight bearing limitations, and poor pavement condition increase runway occupancy times, lower airfield capacity, and may limit the types of aircraft permitted to use a runway. Events such as runway closures or outages of navigational aids can temporarily reduce capacity.

#### **4.2.1.2 Visibility and Meteorological Conditions**

Changes in wind, weather, and visibility are the most important causes of variations in capacity. Particular wind directions can mandate the use of lower capacity runway configurations. Low ceilings, precipitation, and accumulations of snow and ice on the runway can severely restrict aircraft operations or close the airport altogether. The extent to which changes in weather and visibility affect capacity depend to a significant degree on airfield resources, i.e., the type of navigational and landing systems available and the separation of the runways.

Air carrier schedules are based on optimal conditions and the associated airport capacity. If the visibility is at least three statute miles and cloud heights are at least 1,000 feet (VFR conditions), pilots can use visual approaches to the airport. When the visibility is below the minimum required for visual approaches, pilots must fly instrument-aided approaches, operations must be conducted under Instrument Flight Rules (IFR), aircraft must be spaced farther apart, and must fly longer, well-defined approach paths.

Other weather conditions can have dramatic effects on aircraft operations. Thunderstorms can greatly reduce or stop arrivals to an airport, since aircraft cannot safely fly near or through thunderstorms. Snow or ice on the runway surface can also increase the arrival spacing between aircraft because of the reduced effectiveness of aircraft brakes, resulting in longer landing rolls and increased runway occupancy times.

#### **4.2.1.3 Air Traffic Control Procedures**

Air traffic control procedures, which ensure safe separation between aircraft leaving and entering the terminal area, provide greater separation under IFR conditions than are commonly maintained under VFR conditions. Rules regarding the use of converging and parallel runways during instrument operations reduce the use of runways, often limiting an airport to single runway operation when visibility is poor.

#### **4.2.1.4 Noise Abatement Procedures**

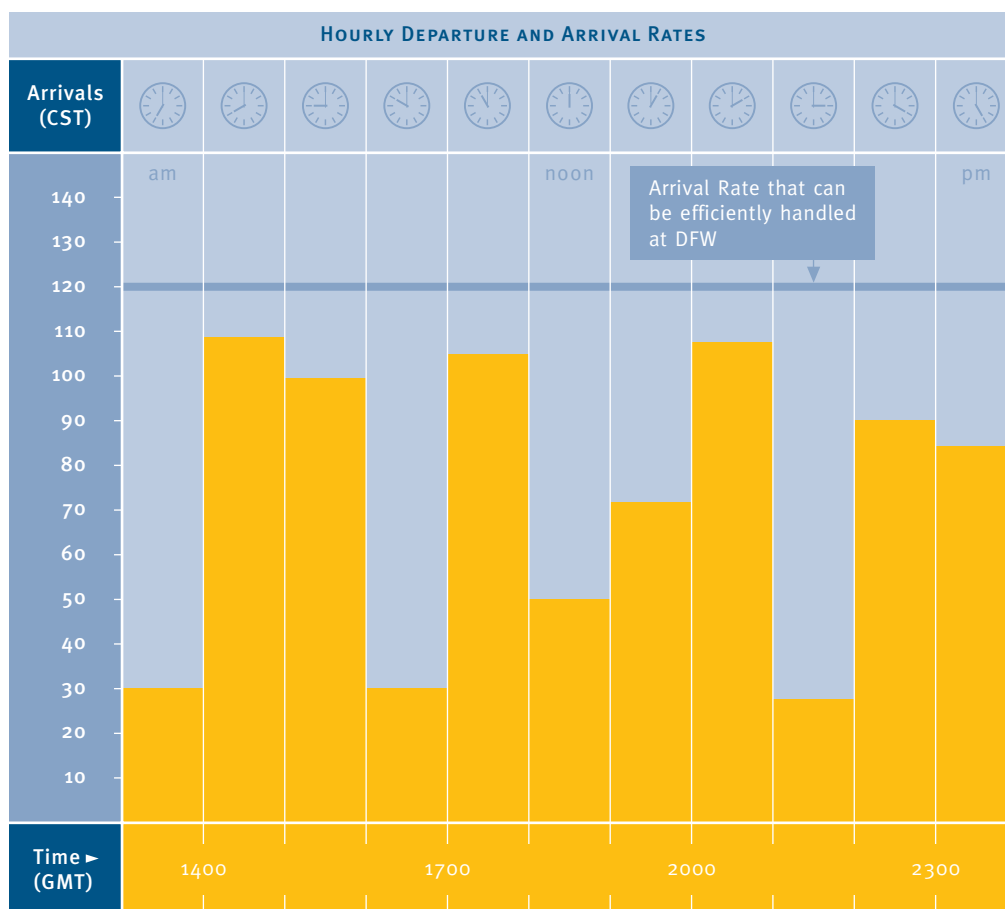
Noise abatement procedures established for an airport can reduce available capacity during certain hours of the day. These procedures generally restrict the use of departure and approach paths that pass over residential areas or limit airport operations at certain times of day. Such restrictions may limit the use of runway configurations with the highest capacity.

### 4.2.1.5 Demand

The pattern of aircraft demand, which refers to the number of aircraft seeking access, as well as their size, weight, performance characteristics, and desired access time, is an important determinant of capacity. The performance characteristics of aircraft affect the rate at which operations can be maintained. For example, to protect smaller planes from wake vortex turbulence, in-trail arrival separation between small and large aircraft must be greater than that required between two large aircraft. The runway occupancy times of different types of aircraft also affect separation requirements and thus capacity. As demand approaches airport capacity, congestion and minor delays begin to occur.

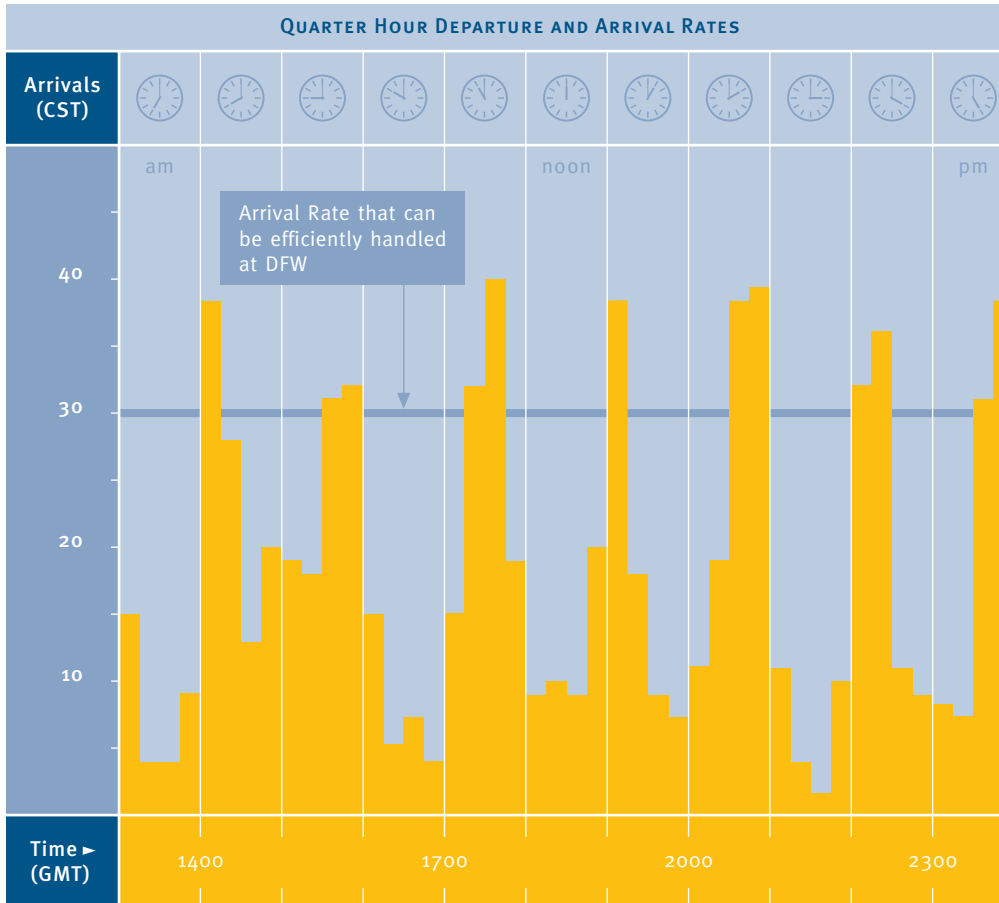
Airport capacity is expressed as the maximum number of operations (takeoffs and landings) that can occur within a given period of time using standard air traffic management practices. This expression of airport capacity assumes that the demand for service is continuous (i.e., that there are always aircraft ready to takeoff or land). NAS capacity would be closer to the maximum if traffic were evenly distributed throughout the day (and night) and among all airports. In practice, however, traffic demand surges and ebbs. This variability is most pronounced at the large hub-and-spoke airports, where a series of banks of flights results in pronounced peaks and troughs in demand. Figure 4-2 shows such a pattern in the daily arrival demand at Dallas/Fort Worth International Airport (DFW), which varies from a high of about 110 flights per hour to a low of 30 flights per hour.

**Figure 4-2**  
Variability in Demand at DFW  
(Hourly)



Source: Federal Aviation Administration, Airport Arrival Demand Chart for DFW, October 31, 2000.

The traffic bank's characteristic peaks in demand and the troughs that follow are more apparent if the daily arrival demand at DFW is plotted in 15-minute intervals. Figure 4-3 shows a very large variation in demand, with one period of 40 flights per quarter hour and a number of periods following or preceding the peaks where the demand is less than ten flights per quarter hour.



**Figure 4-3**  
Variability in Demand at DFW  
(Quarter Hour)

Source: Federal Aviation Administration, Airport Arrival Demand Chart for DFW, October 31, 2000.

Figures 4-2 and 4-3 also illustrate the impact of the variability of demand on airport capacity. In both figures, DFW's hourly capacity is indicated by a horizontal blue line. In Figure 4-2, the hourly capacity of 120 flights is never exceeded, while in Figure 4-3, the airport's capacity of 30 flights per quarter hour (simply 120 divided by four) is exceeded in 12 periods, and from 1730 to 1745 hours the demand exceeds capacity by one third.

#### 4.2.1.6 Airport Congestion

Variability in capacity, combined with the pattern of demand, can cause airport congestion, typically, the formation of aircraft queues awaiting permission to arrive or depart. If demand, on average, is lower than capacity, then occasional surges in demand may be followed by periods of relative idleness during which queues can be dissipated. But when demand approaches or exceeds capacity for extended periods, it becomes increasingly difficult to eliminate backlogs. Any unexpected increase in demand or disruption that reduces capacity, even if it is relatively short-lived, can result in rising levels of delay that may persist throughout the day.